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KNOWLEDGE DEVELOPMENT PATTERNS IN RADICALLY NEW PRODUCT ARCHITECTURES

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ABSTRACT

Knowledge development patterns in radically new product architectures are explored. The aim is to achieve rich insights to generate explanatory propositions from a longitudinal field-study of three years. Results descend from a strategically selected sample pictured by a large industrial corporation up to develop a new product architecture as a principal mean to achieve synergies from an acquisition process. The study demonstrates how knowledge about two domains; components and architecture, simultaneously changes when developing radically new product architectures. Explanatory propositions suggest: (1) architecture to add complexity and uncertainty; (2) components to reduce complexity and uncertainty; (3) and architectural knowledge to be developed from knowledge about components.

Keywords: *Knowledge development, patterns, radical innovation*

INTRODUCTION

Product architectures represent a powerful strategy to accomplish mass production activities (Ulrich, 1995), and to attain product variation offerings to achieve economies of scale and economies of scope (Mikkola, 2006). Its promising potential is founded in logics to apply product architectures across a broad range of distinctively different products (Halman, Hofer et al., 2003; Meyer & Lehnerd, 1997). Based on architectural foundations, companies can obtain advantages from commonality as well as developing differentiated products more efficiently (Robertson & Ulrich, 1998). Without doubt, product architectures represent a key asset and a cornerstone to carry out efficient competition at a product level when applied across product ranges (Halman et al., 2003; Karlsson & Sköld, 2007; Meyer et al., 1997).

In spite of the fact that product architectures may reduce development time and decrease development costs (e.g., Muffatto (1999); Robertson et al. (1998); Sawhney (1998)), product architectures are also subject to a double-edged sword quandary. This challenge and dilemma has received little attention in research and arise when architectures run out of date one day, and face a need to be replaced with new product architectures (Sköld & Karlsson, 2007b). An essential challenge is that new architectures may destroy the usefulness of existing knowledge of established firms, since product strategy, information filters and communication channels are interwoven with architectural knowledge embedded implicitly in various organizational processes (Henderson & Clark, 1990; Sircar, Nerur et al., 2001; Tidd, 1995). Beside this highly established conception, scarce research has investigated why and in what way architectural innovation destroys architectural knowledge. It is especially unclear how knowledge is developed in radically new product architectures.

In order to start investigating this theoretically and practically challenging defy, the paper is designed as an explorative and longitudinal field-study. The aim is to gain rich insights to this sophisticated dilemma to start identifying knowledge development patterns in new product architectures. Undertaking this concern, the next sections are reviewing the fundamentals of architectural innovation and architectural knowledge, before research aim is proposed.

ARCHITECTURAL INNOVATION AND ARCHITECTURAL KNOWLEDGE

ARCHITECTURAL INNOVATION

Henderson et als. (1990) paper is a milestone and a highly cited reference in the fields of innovation management and innovation strategy. Clearly, their contribution is an extension of Abernathy & Clarks (1985) model, resulting in a richer characterization of different types of innovation. Their argument to elaborate on the prevailing framework was motivated with shortcomings in existing categorization of innovation as either radical or incremental (Ettlie & Subramaniam, 2004; Sircar et al., 2001). Henderson et al. (1990) claimed the established framework to be insufficient since they noticed firms to develop products that did not fit with the radical or incremental classification. In complementing prevailing paradigm, they are more known for architectural than modular innovation as a new important category of innovation (Ettlie et al., 2004).

Along the continuum, an innovation can be placed anywhere from incremental to radical innovation depending on the extent to which components or architecture are affected (Sircar et al., 2001). The basic principle is that architectural innovation change the way components are linked together, while leaving core design concepts, such as components etc, untouched (Henderson et al., 1990). Consequently, architectural innovation result in changes according to: schemes by which functions of products are allocated to physical components, arrangement of functional elements, mapping from functional elements to physical components, and specifications of interfaces among interacting physical components (Ulrich, 1995). Since architectures comprise a number of distinct subsystems, and each of the various subsystems is in turn composed of other subsystems and ultimately components (Venkatesan, 1992), architectural changes have profound implications on existing architectural knowledge that becomes obsolete to certain extents (Henderson et al., 1990).

ARCHITECTURAL KNOWLEDGE

Because of the impact of existing architectural knowledge, architectural innovation is considered more radical and more competence destroying than innovations at the component level (Schilling, 2005). The reason for its impact depends on architectural knowledge to be embedded in structures and information systems, representing old products and architectures in terms of how components relate to each other (Richard & Devinney, 2005; Tidd, 1995). Architectural innovations are concerned not only with product and process innovations, but also with strategic innovations which reconfigure knowledge into new approaches to competing (Grant, 1996). Introducing new architectural innovation may therefore destroy old architectural knowledge since knowledge is related to un-valuable architectures (Teece, Rumelt et al., 1994). Hence, old architectural knowledge become obsolete when new architectural innovations are introduced (Henderson et al., 1990).

Architectural knowledge can be understood as intimately detailed and specialized power of translation required to capture customer requirements and to reproduce requirements in the language of subsystem performance specifications (Venkatesan, 1992). Architectural knowledge both contain information of the product as an entirety, and the product in its parts (Henderson et al., 1990; Van de Ven, 1986). It is based on detailed understandings of the linkages between user requirements, system parameters, and component specifications, it is unique to each company, intuitively developed in countless conversations by teams of strategists, designers, and marketing people (Venkatesan, 1992). However, according to Henderson et al. (1990), it is unclear what drives effective learning about new architectures and how learning about components is related to this process.

RESEARCH AIM

According to the research aim; to identify and explain knowledge development patterns when developing new product architectures, the paper is guided by two statements from previous research on architectural innovation and architectural knowledge. In summary, most focus on architectural innovation is for natural reasons concentrated on the effects of architectural knowledge, little or almost nothing on the effects on component knowledge since it is architectural knowledge that is becoming changed and obsolete in

architectural innovation. At the same time it is worth paying attention to Henderson et als. (1990) statement; that it is unclear what drives effective learning about new architectures and how learning about components is related to this process.

From the review, two questions are addressed. Firstly, is it sufficient to put all focus on architectural knowledge in architectural innovation? Secondly, are components having an indirect significance when it comes to knowledge development in architectural innovation? Hence, one question combines the two others in guiding the explorative research aim of the paper: *What patterns characterize knowledge development in architectural innovation?*

RESEARCH METHODOLOGY AND METHODS

SAMPLING FRAME

The nature of investigation is explorative to mirror interests in identifying knowledge development patterns. An explorative empirical frame was created (e.g., Karlsson & Lovén (2005)), to make a clear distinction between knowledge about components and knowledge about architecture since both are supposed to influence knowledge development patterns (see figure 1). The frame descend from Henderson et als. (1990) statement; that it is unclear what drives effective learning about new architectures and how learning about components is related in the process. Based on the empirical frame, knowledge development is assumed traceable in relation to four conditions, making a distinction between component and architectural knowledge. Component knowledge is defined as knowledge about individual components, architectural knowledge how components are arranged in larger systems (Prencipe, 2000).

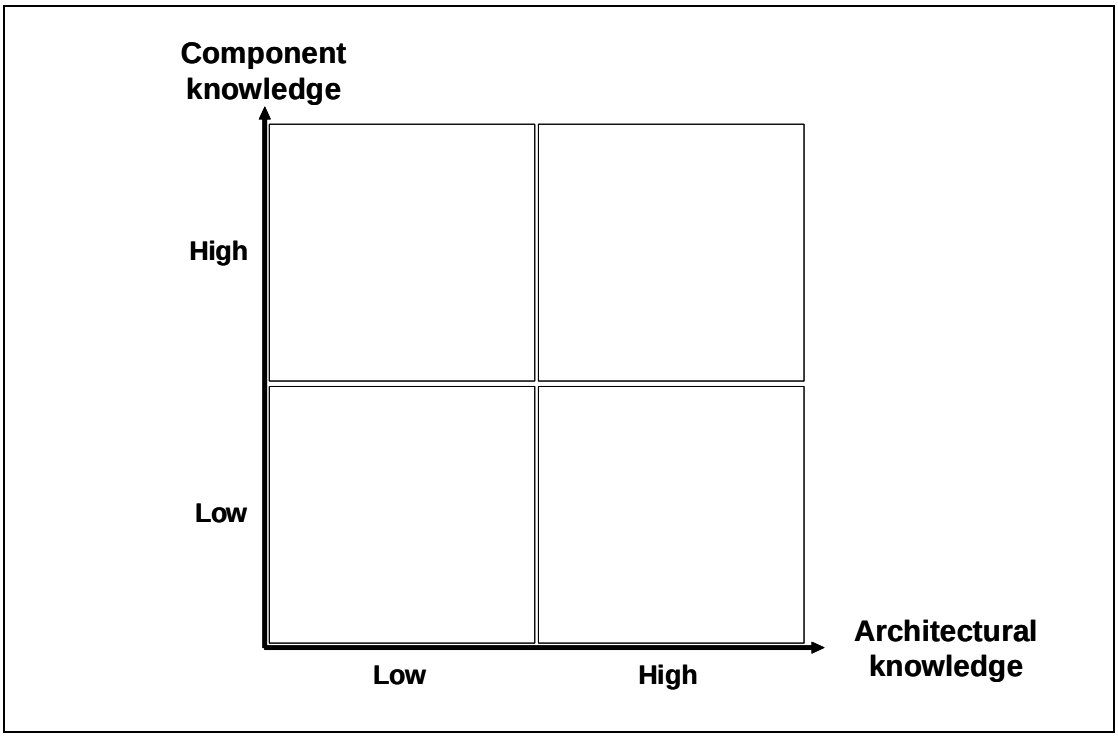

Figure 1. Empirical frame

RESEARCH DESIGN

The research design is grounded to facilitate identification of knowledge development patterns in architectural innovation. To be able to depict partly un-known patterns, the use of a process-focused and longitudinal case study was chosen (Eisenhardt, 1989; Leonard-Barton, 1990). The longitudinal design were assumed proper to study a change phenomenon by admitting data collection at several points over time (Malhotra & Grover, 1998). Hence, the research design is based on an explorative and longitudinal field-study methodology to assure in-depth and rich data (Voss, Tsikriktsis et al., 2002), to identify patterns supposed to hold certain complexity and unknown dimensions (Sköld & Karlsson, 2007a). The explorative and longitudinal approach is believed to achieve the finest insights into a yet incompletely documented phenomenon (Burgelman, 1983).

STRATEGIC SAMPLE

One large industrial group from an automotive industry was chosen as a strategic sample (hereafter called "the corporation"). "The corporation" is developing, manufacturing, and selling a broad range of end-products at a global presence in various application areas. Choosing "the corporation" as a strategic sample was emphasized by corporate decision to develop a radically new product architecture between two companies from an acquisition process. The new architecture represented the central strategy to achieve operational synergies from an expanded product range. Focusing proceedings of architectural development was regarded as a unique opportunity to accomplish research longitudinally (Van de Ven & Huber, 1990; Yin, 1994).

CASE SELECTION

The research prelude is based on a situation where a senior vice president from the corporation asked for help with overhauling architectural developments, not by researchers deciding what to study (Schein, 2001). A meeting with the senior vice president subsequently created a mutual plan of how to pursue research from an ongoing organizational change process and simultaneously conducts research (Lawler III, 1985; Schein, 1987; Starkey & Tempest, 2004). The basic building-block was to participate and to create knowledge from action within the organization (Coughlan & Coghlan, 2002). Furthermore, an agreement was made to concentrate field-works to a specific development project, responsible for architectural development. The project was cross-functional and included about 450 people from; product development, manufacturing, purchasing, product planning, production, sales and marketing. The product development organization was key-responsible.

DATA COLLECTION AND ANALYSIS

Data is collected from three methods. An important source is participant observations in various development meetings, sometimes involving 100-300 persons from the whole corporation. A second method is interviews, mainly with managers from product development, manufacturing, purchasing, product planning, production and marketing. A third method consists of written documents describing development principles, plans, and definitions. During a period of three years; 80 days where spent within the

corporation, 74 interviews fulfilled, and participation in 27 meetings represent the foundation for data collection.

Data reduction and analysis were accomplished in six steps. Field-notes were firstly taken in shorthand by pen and paper. These were thereafter transcribed into Word-documents, saved as separate files with dates. As a third step, critical incidents were identified according to ambiguous and/or equivocal statements of critical incidents nature (Flanagan, 1954), made by people in various empirical situations. Incidents were subsequently inserted into an Excel-document to facilitate sort ascending (e.g., Frankfort-Nachmias & Nachmias (1996); Miles & Huberman (1994)). Thereafter, in a fourth step, incidents were related to aggregate themes representing larger parts and constructs to consider. Identified incidents and constructs were in a fifth and highly important step validated by managers at data-feedback and workshop meetings. Reiterating workshop meetings at quarterly frequencies, facilitated identification of knowledge development patterns into coherent themes (e.g., Mintzberg (1972); Pettigrew (1990)). Emerging patterns were compared and validated with knowledge from existing theory (Eisenhardt, 1989).

STRUCTURING THE EMPIRICAL BASE

INTRODUCING "THE CORPORATION"

The industry in focus has witnessed several changes during last decades. Mergers and acquisitions between end-producers and suppliers describe preconditions and characteristics of the industry. Because of an intensified pressure on cost-cuts, the industry is dominated by volume driven business-models and management. The industry is also questioned because of tough environmental demands creating critically important agendas driving innovative efforts in almost every field of technology.

STRATEGIC AND ORGANIZATIONAL CHANGE

In order to enhance competitiveness and to secure competition in the long run, "the Corporation" has divested several business areas in the past ten years. The motive was to streamline the organization to put considerable efforts within prioritized industrial segments. "The Corporation" has also acquired a company from the industry to enlarge product scope and to create operational synergies from economies of scale. Synergies were planned to be realized from the development of a common product architecture between products from the two companies. To emphasize goal, and to clarify the strategy, the CEO put out two goals; the new architecture should aim to achieve high commonality, and high brand distinction.

Organizational changes were accomplished to support realization of synergies from architectural development. One was carried out at business area levels, when marketing and sales units from the two companies were organized as separate business units. Another occurred at a business unit level when people from functional disciplines were co-organized to facilitate synergies from joint activities and knowledge sharing. Architectural development was carried out in a large project in the new organization, involving about 450 persons equally distributed between the two companies. The project was supervised by two senior project leaders from product planning and product

development. Both had their history from the acquiring company with lots of experiences of architectural development projects from the past.

THE NEW ARCHITECTURE

The project in focus was founded in available experiences and knowledge about developing new architectures. This was visible in definitions, conceptualizations, and applied terminology. Even if people from the two companies claimed to have experiences from the past of architectural development, the new architecture was hard to understand because of its new and enlarged product scope. Engineers from the acquired company asserted to have appropriate architectural experiences but expressed statements of not recognizing patterns of the new one. Engineers from the acquiring company made corresponding statements, confused since principles had been reliable in the past. The new architecture was perceived different from previous experiences and knowledge. Chief engineers from the acquired company proclaimed a need for relevant definitions and tools since the new architecture was not understood by people from various organizations.

HETEROGENEOUS EXPERIENCES

The acquisition between the two companies increased the total number of components from 20.000, to 40.000 parts. Consequently, 20.000 components were un-known for people from one of the two companies. Respondents, such as project leaders, engineers, and chief engineers, explained the situation as extremely complex due to the large amount of components. Hence, development efforts were initially attempting to reduce the quantity of components by finding common parts. The commonality approach was successful and resulted in large amounts of common components, partly in line with the aim of creating operational synergies. Thus, the common component approach was also subject to lots of criticism. Engineers inquired detailed principles and definitions defining precise interfaces and geometry for the new architecture. Managers from marketing and sales departments emphasized the importance to focus distinction as an important dimension of the new architecture. Responsible project leaders argued that complementary principles did not exist or did not function for the actual situation.

DEVELOPMENT APPROACH

Even if people from the two companies were familiar with developing new product architectures, managers from the acquiring company made several and influential statements in the development process. Systems engineers and architectural engineers inquired it essential to focus elements of architecture instead of common components. At an internal product development meeting, the CEO of Machine Products made a memorable statement with the aim to influence development work. The CEO defined the new architecture in terms of common technology, instead of components. The statement met approval and contributed with understanding that the development work had a broader scope than simply focusing common component solutions. Slowly, interfaces and geometrical dimensions were invented between some and important components. Hence, components were still the dominating approach in developing the new architecture. Engineers emphasized it easier to focus components than architecture.

ANALYSIS

The sample of this study is chosen to reflect interests in tracing knowledge development patterns in architectural innovation. According to this concern, it is important to clarify characteristics of the case. First of all, architectural innovation is explored in a situation of developing a new product architecture between two companies in a merger process. Similar findings are not found in literature on architectural innovation and product architectures (e.g., Henderson et al. (1990); Meyer et al. (1997); Robertson et al. (1998); Ulrich (1995)). Consequently, a basic assumption is that previous research has not dealt with similar situations when architectural innovation involve new and un-known products to be included in new architectures, as from an acquisition process. As a consequence of developing new architectures based on new products and components outside an established architectural scope, architectural innovation can also entail changes in a component dimension which is a new angle from the study. Secondly, we face a situation when radically new product architectures cause changes to architecture as well as components.

Changes according to components and architecture are inevitable, at least to some extent, in radically new architectural innovation. This is first of all a consequence of the fact that a new architecture is aimed to be developed. Secondly, it is also an outcome because new components are added from new products included into the scope. Results from the study shows that this situation is causing tremendous complexity linked to knowledge about components and architecture, commonly found in radical innovation (compare; Ettlie et al. (2004); Henderson et al. (1990); Sircar et al. (2001)). Changes in relation to components spring from the fact that new components are added from products not included in previous architectures or product scopes, and changes in relation to architectures arise because old architectures become obsolete and out of function.

Radically new architectural innovation originates from an inevitable starting-point of changed and obsolete knowledge about components and architecture (see figure 2), causing several implications to knowledge development patterns. Firstly and already concluded, radically new architectural innovation descend in a starting-point of low levels of commonly shared knowledge about components and architecture (see figure 2) according to Prencipes (2000) definitions; component knowledge is defined as knowledge about individual components, and architectural knowledge how components are arranged in larger systems. From this position, knowledge development could, at least in theory, take any direction according to knowledge about components and/or architecture.

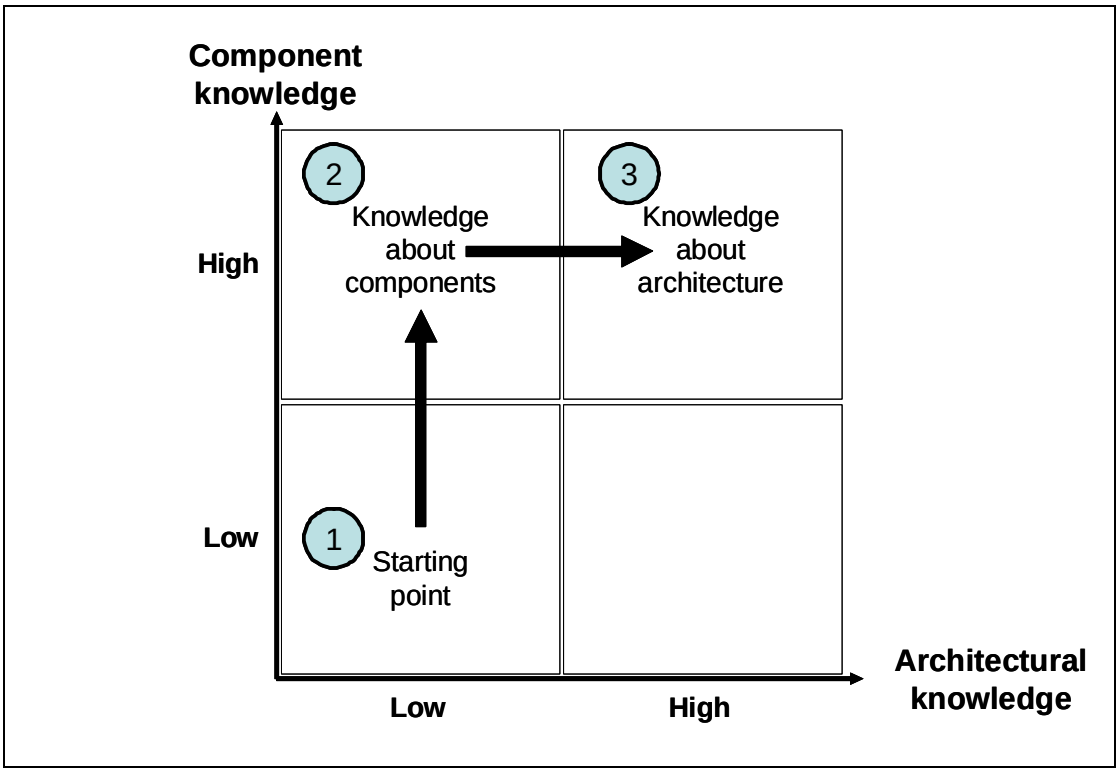

Figure 2. Patterns of knowledge development in radically new architectural innovation

Hence, triangulated results from the study shows that knowledge about components tends to dominate knowledge development patterns, illustrated with the arrow in the upper left quadrant. The reason for this lapse is explained by extensive complexity and uncertainty when components as well as architecture are changing. In a very complex situation components seems easier to focus than architecture. As a third step, new knowledge development patterns are identified according to knowledge about architecture. This proceeding tends to occur when complexity and uncertainty is lowered about components. In a situation of reduced complexity and uncertainty about components, knowledge development patterns may change direction towards knowledge about architecture (see figure 2).

KNOWLEDGE DEVELOPMENT PATTERNS IN RADICALLY NEW ARCHITECTURAL INNOVATION

From previous sections we have a foundation and framework to explore knowledge development patterns when developing radically new product architectures. From the analysis we can also confirm radically new architectures as a knowledge destroying strategy (e.g., Christensen (1997); Tushman & Anderson (1986)), because of its disruptive and discontinuous elements. Its knowledge destroying characteristics is highly visible in the case-study portraying architectural innovation as a “Carte Blanche” strategy; starting in a position of low levels of knowledge about components, and low levels of knowledge about architecture. Thus, radically new architectural innovation is a destructive strategy jeopardizing the usefulness of valuable and firm specific resources (e.g., Henderson et al. (1990); Schumpeter (1942)).

The study is supporting the established convention that architectural innovation destroy the usefulness of existing architectural knowledge of established firms (Henderson et al., 1990). However, the study also notices interesting patterns about components as important building-blocks for the creation of architectural knowledge. For this concern, knowledge development patterns are emanating from a position of low levels of knowledge about components and architecture. Thereafter, knowledge development patterns are concentrated to knowledge about components. Thirdly, when sufficient knowledge is developed about components, knowledge development patterns may change direction towards knowledge about architecture. Hence, important interplays and sequences is consequently identified according to knowledge development between components and architecture. This finding is further discussed in the two sections ahead.

KNOWLEDGE DEVELOPMENT PATTERNS ABOUT COMPONENTS

Radically new architectural innovation originates in a position of low levels of knowledge about components. This finding is a bit unexpected since prevailing theory about architectural innovation rather portray the importance of architecture. In the same breath it is important to clarify that previous writings has focused the knowledge destroying parameter of architectural innovation (Henderson et al., 1990; Sircar et al., 2001; Tidd, 1995), in contrast to this study aiming to depict the opposite in terms of knowledge re-creation patterns. Hence, the basis for an inevitable starting point of low levels of knowledge about components is that new components are added from products not involved in previous architectures, e.g., when architectures are developed across former separated product ranges within enterprises or in mergers and acquisitions. As a result, people from each product range have knowledge about components emanating from one part of the entire product scope.

Changing and expanding an architectural scope, create tremendous complexity expressed at the level of components. This complexity originates from a mixture of knowledge about specific constructions and designs blended together in a widespread quantity of unique components. In truly complex situations including thousands of un-known components, radically new product architectures find evolutionary paths reducing complexity and uncertainty, e.g., commonality approaches regarding components. Knowledge is hence materialized into physical components (Takeishi, 2002), before un-physical assets, indicating knowledge development, in a first step to be facilitated if materialized before immaterialized. For this reason, it is here proposed that components reduce complexity and uncertainty. Therefore, patterns of new knowledge development is initially emanating from knowledge about components.

KNOWLEDGE DEVELOPMENT PATTERNS ABOUT ARCHITECTURE

Radically new architectural innovation originates in a position of low levels of knowledge about architecture. This pattern is expected and supported in previous research emphasizing architectural knowledge to become obsolete in architectural innovation. The complexity has its origins from the situation of bringing previously separated architectures together for a new common architecture. According to Henderson et al. (1990), architectural knowledge has it roots and is affected by factors such as history and culture. Consequently, the starting-point of radically new

architectural innovation has its origin in diverse and specific architectures. Thus, architectural knowledge is firm, and product range specific assets (e.g., Venkatesan (1992)), and initially not shared between people across product ranges in the starting-point when developing radically new product architectures.

Regarding the complexity at a component level, developing new architectures is an even more complex defy because of the tacit and intangible nature of architectures. Therefore it is proposed that architecture add complexity and uncertainty. Hence, it seems as a utopia to start architectural innovation with developing new architectures. Instead new architectures seem to represent an outcome of new knowledge stemming from knowledge about components in the first place. Thus, knowledge about architectures is proposed to be learned from knowledge about components, since architectural knowledge is embedded in components. Consequently, knowledge about architecture does not exist until sufficient knowledge about components is developed. Adequate knowledge about architecture is consequently not available beforehand.

CONCLUSIONS

The aim and research question of the paper is to identify patterns of knowledge development when developing radically new product architectures. Because of the limited sample, findings are presented as propositions rather than statistically validated conclusions. Results from the study both support and un-support findings from previous research. A first proposition emphasizes knowledge development patterns in radically new product architectures to be developed from knowledge about components. This proposition implies components to have a much more important influence than what is found in previous literature. This finding is further explained in a second proposition suggesting components to reduce complexity and uncertainty because of its tangible nature. Hence, knowledge developments proceed from components as tangible footholds in complex endeavours since architectures are associated with tremendous complexity and uncertainty because of its intangible characteristics. Accordingly, a third proposition advocate knowledge about architectures to develop from knowledge about components. Together the three propositions explain starting points and patterns of knowledge development when developing radically new product architectures.

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